AN INTRODUCTORY SCIENCE COURSE FOR SECONDARY SCHOOLS

THE proper sequence of scientific subjects in high schools is a question of steadily increasing importance, which seems to baffle all attempts at a satisfactory solution. It resolves itself into a controversy between the physical sciences on the one hand and the biological and geological on the other.

It is generally recognized that the physical sciences are much more fundamental than the other natural sciences. The former supply the majority of facts and principles on which the latter are based. Says Professor C. E. Bessey in a committee report to the Nebraska Teachers Association: "It is only a superficial knowledge of plants and animals which may be obtained without some aid from chemistry and physics." Much of the latter work must also be given before the pupil can understand the relation of the earth, sun, winds, rainfall, disintegration of rock, origin of limestone and rock salt, and other important chapters of physical geography. For these reasons the plea is frequently put forth that physics and chemistry should be studied before all other natural sciences.

On the other hand, any experienced teacher will at once think of many reasons why impulsive and awkward fifteen-year olds, with scant mathematical training should not be introduced to a standard physical laboratory, and numerous arguments also for not giving sophomores the liberties of an experimental desk in chemistry. Whatever order of presentation be followed, there is more or less dissatisfaction.

There is another unfortunate feature of science work in secondary schools, due possibly to illogical sequence, viz., the abrupt manner in which students are thrown with the opening of each year into the different special sciences. Our high-school science lacks unity.

In the fall semester 1900, there was introduced in the Lincoln High School an innovation, somewhat in the way of an

experiment, looking forward to the solution of the above problem. While the investigation is not yet complete, the successful results obtained during two semesters with several hundred pupils lead us to think that a report may be interesting to educators.

It seemed possible that a one-semester course for beginning ninth-graders might be constructed so as to include an experimental study of the important properties of matter and the simpler illustrations of forms of energy and chemical action, with special reference to physiography and biology and to the simple familiar phenomena of daily life. It was also fully realized that the course should be, not a series of disconnected lessons, but a thoroughly unified study and therefore a fitting gateway to the fields of science which follow.

The course included three days (two periods each) laboratory work and two days lecture and recitation per week. No textbook was used. The course was based on the individual experimental work of the student, supplemented by class discussions, demonstrations, lectures, and quizzes. Mimeograph instructions were provided for laboratory work. The apparatus was simple, being frequently devised by pupils or teachers, and was provided in sufficient quantity that each student might perform experiments in their logical order. Wherever possible, the inductive method was used. A reference library has been carefully selected and a list of supplementary readings prepared, explaining the applications of the various general truths discovered.

The following is a brief outline of the course:

1. OBSERVATION.—The course starts from a psychological standpoint. The use of each sense in furnishing knowledge is pointed out in class and the first laboratory exercise deals with the examination of different objects and a description of their qualities. Hereupon the *scientific method of study*, the advancing from facts to theories, is explained. Throughout the succeeding exercises the student is directed, whenever possible, to compare related phenomena, suggest an explanation of them and devise a means of testing the validity of his hypothesis. Gradually

that much abused term, "scientific method," comes to have a real meaning.

2. MATTER. *a. Definitions.*—The fundamental concepts of matter, body, substance, position, motion, force, etc. are made clear.

b. Measurement.—Then follow several exercises in measurement, teaching accuracy and self-reliance. The student is introduced to the meter-stick, the metric graduate and the metric weights, learns the advantage of the metric system and finds experimentally the comparative value of centimeters and inches, of liters and pints and of kilograms and pounds. The exercises are those usually found in the best elementary physics manuals. Before the practice in weighing, a balance is constructed from a stick, some thread and pill-boxes, and the "principle of the balance" worked out individually. Some determinations of absolute density follow.

c. Properties of matter.—A few experiments were selected to illustrate each of the following general and specific properities of matter: inertia; divisibility; indestructibility; impenetrability; porosity; compressibility and expansibility; elasticity; mass attraction; molecular attraction; solubility; transparency; color; odor; taste.

We have found it distinctly advantageous to emphasize the meanings, with little heed for the names, of these properties. Such cumbrous terms serve only to stifle the enthusiasm of the beginner over the simplicity of science. Divisibility and the approximate size of molecules is illustrated by diluting a solution of aniline-red of known concentration till the color is just visible; solubility by comparing the miscibility of liquids and the extent to which various solids dissolve in water under different conditions, simple quantitative experiments being much preferable to estimations with the eye. In connection with the latter property the importance of the solubility of the food materials of plants is brought out. The cause of tides and the holding in place of the bodies of the solar system is touched upon under gravitation.

d. Properties of solids.—Some well-known minerals are examined in one exercise, as to the distinctive properties of solids, such as hardness, tenacity, transparency, and form. Another exercise deals with the production and description of crystals of different substances, after which a little attention is given in lectures to the internal structure of crystals, their constancy of form, and the relation of the form to the substance.

e. Properties of liquids.—Surface tension and capillarity are studied by numerous experiments. References are read on capillary action in the soil and in the nutrition of plants.

f. Properties of fluids.—Diffusion and pressure. These are studied thoroughly in the laboratory. The student learns enough about osmosis to enable him to understand its importance in cell-nutrition. The variation of pressure in liquids and gases with the depth is illustrated and particular stress laid on the study of the *barometer* and its use in meteorology.

3. ENERGY.—*Heat* is selected as a typical form of energy, since its effects are so important in earthly phenomena.

a. The effects of heat, viz., change of state, change of temperature, and change of size, can easily be illustrated.

b. Thermometry.—Both Fahrenheit and Centigrade thermometer are studied and the fixed points of each determined in the laboratory. The effect of dissolved matter and change of pressure on the boiling-point and freezing-point of water may also be shown.

c. Transfer of heat.—Conduction, convection, and radiation. Particularly the last two are essential to a proper understanding of biology and geology. The cause of winds is brought out here.

d. Density changes of water.—After learning experimentally that water has a maximum density point a little above zero degrees Centigrade, and that water expands on freezing, the beginner is able to understand how rocks are disintegrated in winter and how water-life is protected from freezing.

e. Evaporation and condensation.—A brief study of this makes clear the presence and action of moisture in the air.

f. Transformation of heat into different forms of energy. Here the different forms of energy are observed and the conservation of energy emphasized, together with the derivation of all forms of energy from the sun's heat.

4. CHEMICAL ACTION.—The first few experiments of elementary chemistry, viz., those on physical and chemical changes, combustion and its cause, composition of the atmosphere, and possibly also the dry heating of animal and vegetable matter, serve to give the student knowledge of many of the changes in nature and their causes, the composition of organic tissues and the character of some of the most important elements and compounds.

5. ANIMATED MATTER.—If time remains, one period may be devoted to a microscopic observation and study of the simple living cell. This greatly broadens the course, for it opens the way for the farther study of animated matter subsequently.

The last lecture of all is given up to a general discussion of the different sciences, viz., (1) physiography, (2) botany, (3) physics, etc. The scope of each is outlined and the unity of all science is emphasized. In a later semester, when, *e. g.*, the biology instructor commences his work, he simply has to pick up the thread of thought and carry it farther into his field. The author has no doubt but that the succeeding sciences will be revealed to the pupils in a far better way than has heretofore been done.

The value of this course lies not simply in its being an introduction to the various sciences. To the many students who abandon high school after one or two semesters it furnishes a comprehensive and immensely valuable knowledge of science, especially of its methods and its fundamental importance in daily life. About two hundred and fifty references to "common things" were made during the course, and the pupils who have studied science but this one semester are wide-awake to the scientific aspects of daily life.

In our school the beginning mathematics is intimately correlated with this course. Algebra teachers are able to use a

great deal of the information gained from it in illustrating mathematical principles and devising problems.

Such a course as this would be especially valuable and practicable in the night schools of large cities for those who are anxious to learn a little about science, particularly since the apparatus is so inexpensive.

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